HoloNav: HoloLens as a surgical navigation system

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① Background

- Surgical navigation is a method to guide the surgeon through the surgery using medical images on a screen as map[1].
- With the use of surgical navigation technology surgeons can find the exact surgical site.
- When using this method, the surgeon switches their focus continuously between the surgical site and the screen. This affects hand-eye coordination.
- Augmented reality could overcome this issue. Therefore, The HoloLens 2 is used [2] to create the augmented reality surgical navigation tool called the HoloNav.

The HoloNav

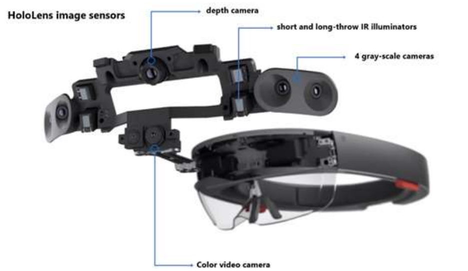

Figure 1: The HoloNav and its cameras

③ Methodology

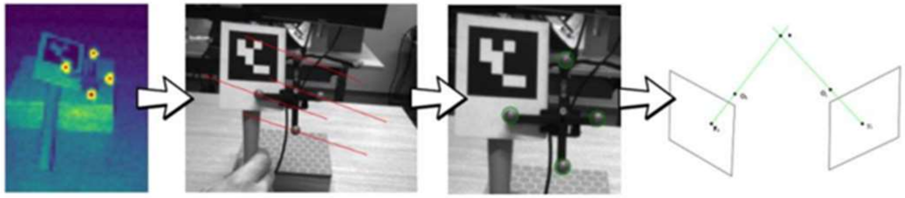

Figure 2:
Stage 1: Locate the spheres on the infrared image with Blob Detection. Stage2: Reduce the search space to lines.
Stage 3: Find the spheres on the grayscale images with OpenCV Template Matching. Stage 4: Triangulation.

- Figure 3 can be used to translate infrared pixel and camera space coordinates to grayscale pixels. This is needed in stage 2 of the method
- The mapping in Figure 3 also needs to be used after triangulation. The triangulated coordinates need to be compared to the optically tracked coordinates. In order to do this, the optically tracked coordinated need to be translated to HoloNav-world space coordinates first.

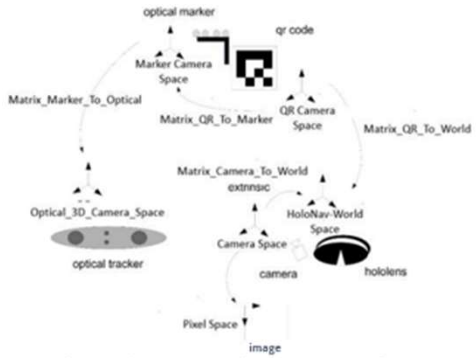

Figure 3: The coordinate mapping between images, their corresponding camera space and HoloNav-world space and the more elaborate mapping from markers to optical and HoloNav-world space through the use of the QR-codes in the images.

④ Results

Results

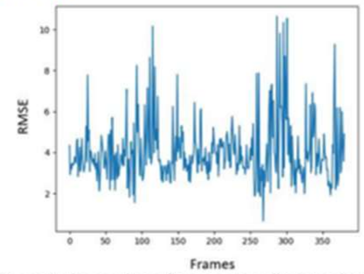

Figure 4: The resulting distances in millimetres between the triangulated coordinates and the optically tracked coordinates expressed in root mean square error (RMSE) per frame.

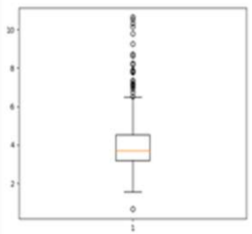

Figure 5: Boxplot of all RMSE results in millimeter.

- Min: 0.66 mm
- Max: 10.64 mm
- Mean: 4.07 mm

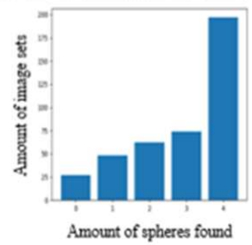

Figure 6: The success rate of Template Matching

- Only spheres with a resulting distance of smaller than the sphere radius (11.5 mm) influence the RMSE of an image set.

② Research Question

Should the HoloNav make use of stereo grayscale cameras combined with the HoloLens 2 infrared sensor to make the 3D optical tracking more accurate?

- How can the 2D location of the optical reflective spheres be found on the grayscale images with the use of an infrared image?
- How can those locations on the grayscale images be used to find the 3D location of the optical spheres?
- How can the accuracy be measured and compared?

⑤ Conclusion

- The method yields accurate results. The results are similar to results from related experiments that are conducted under more favorable conditions.
- The results vary as they depend on how accurate the Template Matching in Stage 3 of the method finds a specific sphere.
- For future work, the geometric relation between sphere positions can be used to achieve higher accuracy, find more spheres and rely less on Template Matching.

[1] U. Mezger, C. Jendrewski, M. Bartels, Navigation in surgery, Langenbecks Arch Surg (2013). [2] S. Park, S. Bokijonov, Y. Choi, Review of Microsoft Hololens Applications over the Past Five Years, Appl. Sci (2021)

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The HoloNav

Figure 1: The HoloNav and its cameras

② Research Question

Should the HoloNav make use of stereo grayscale cameras combined with the HoloLens 2 infrared sensor to make the 3D optical tracking more accurate?

- How can we use the infrared image to find the 2D pixel coordinates of the optical reflective spheres on the stereo greyscale images?
- How can we find the 3D location of the optical spheres when their 2D pixel coordinates are known on the grey scale images
- How can the accuracy of the resulting 3D points be measured and compared

③ Methodology

- **Find the optical reflective sphere locations in the grey scale images**
  - Find the depth lines through the spheres on the infrared image
  - Project the 3D depth lines through the infrared image on the greyscale images with the use of matrix multiplication.
  - Search those lines to find the spheres with edge detection

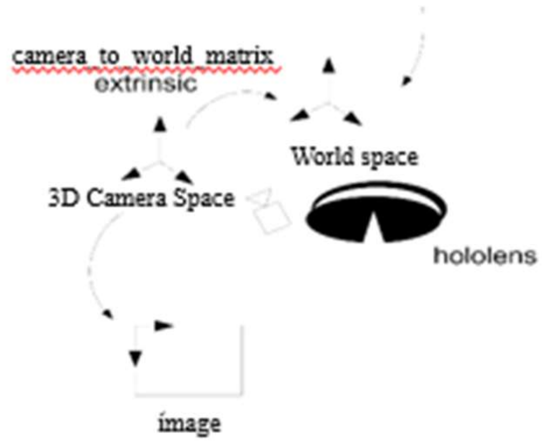


Figure 2: matrix transformations

- **Find the 3D location of the op reflective spheres through triangulation**
  - Find the 3D depth lines through sphere locations in the left and right greyscale images
  - Calculate for each sphere where the 3D lines that correspond to that specific sphere intersect.

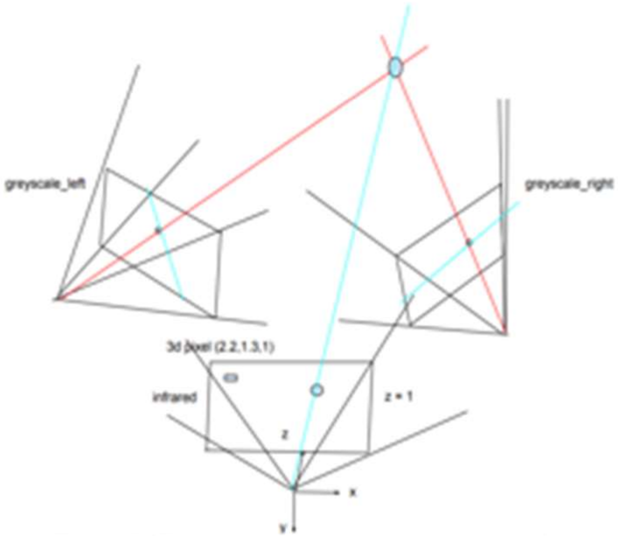
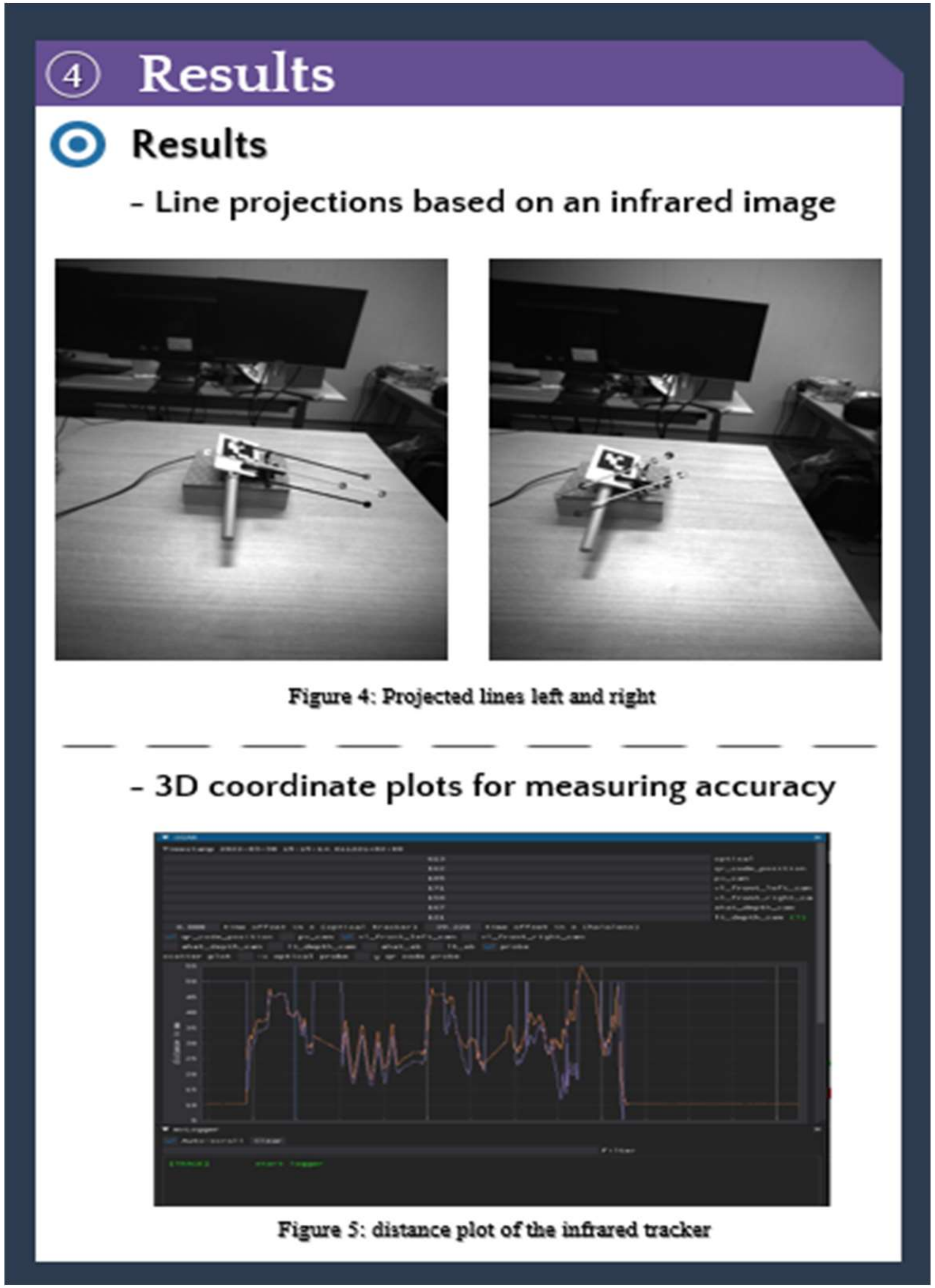
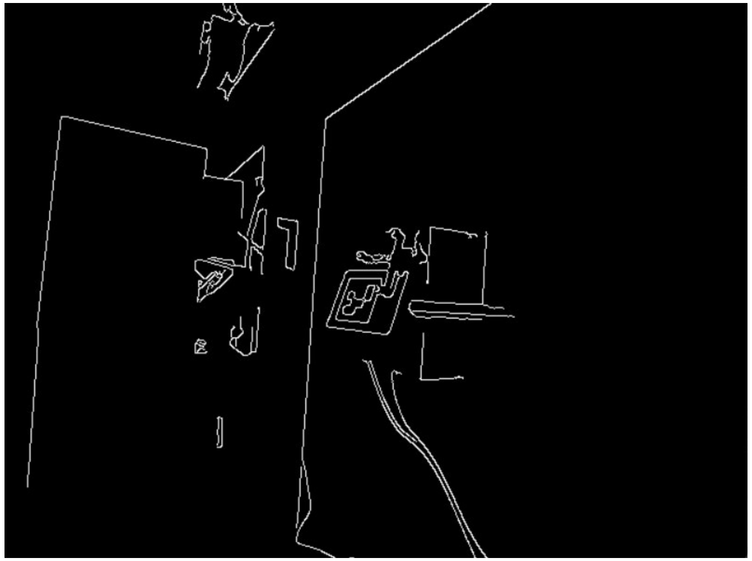


Figure 3: The space and triangulation visualization

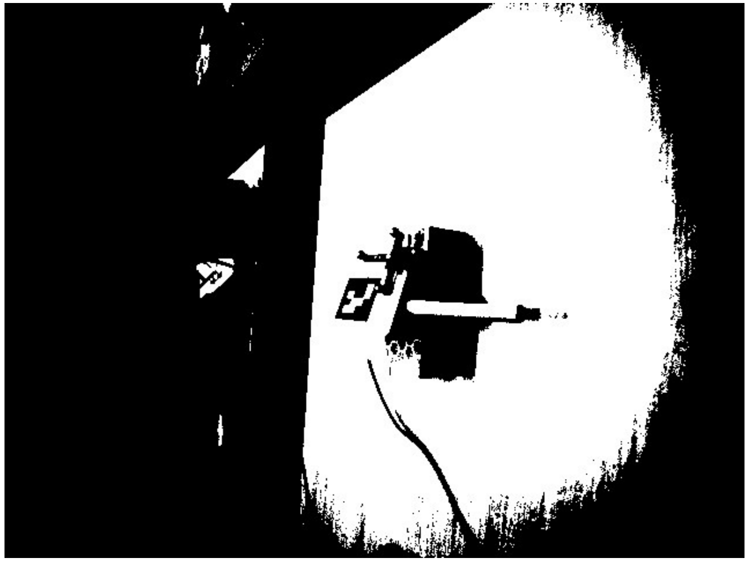
- **Measure accuracy and compare**
  - Plot resulting distances between the resulting depth coordinates and the actual known 3D coordinates for multiple sets of greyscale and infrared images
  - Do the same thing for other optical tracking methods and compare



Canny Edge Detection



Binary Thresholding



⑤ Conclusion

- Comparing plots should determine if the new method used to calculate the 3D positions of the spheres outperform the old method

- Optimizing the method by finding a mathematical correlation between the sphere locations as future work

- Min: 0.66 mm, Max: 10.64 mm, Mean: 4.07mm

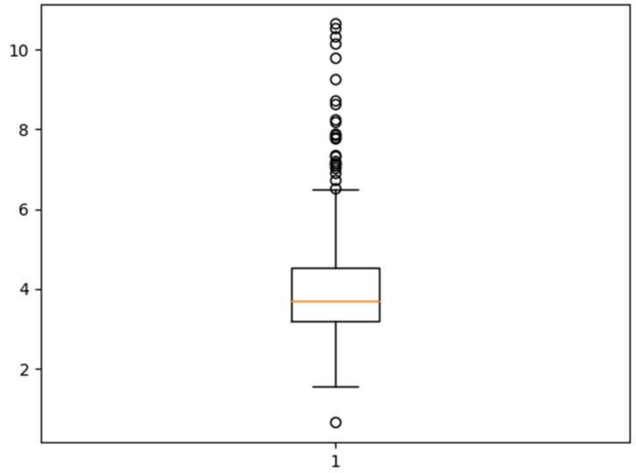


Figure 5: Boxplot of all RMSE results

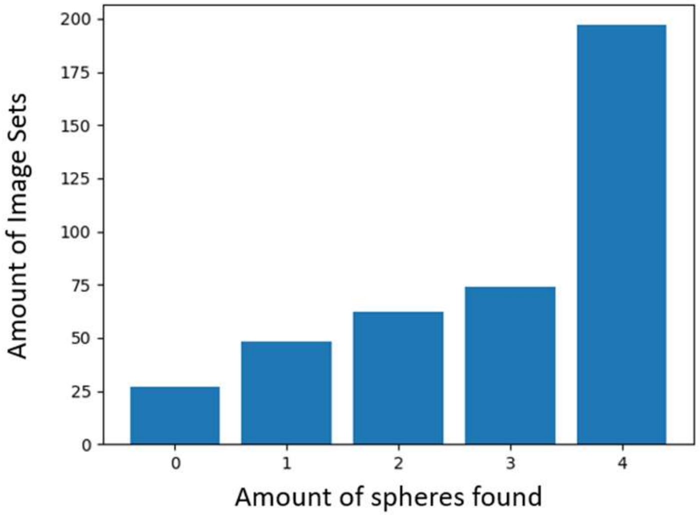


Figure 6: This figure shows how often a certain amount of spheres are found. As there is a maximum of four spheres to be found per image set, every image set can locate 0-4 spheres.